Double Displacement Reactions

- What you will learn…
  - Predict the solubility of a product and if precipiate is formed using solubility information
  - Perdict weather a reaction occurs
  - Write a complete balanced equation for a double displacement reaction

Solubility

- The **solubility** of a solute is the amount that can be dissolved in a given quantity of solvent at a given temperature.

  e.g. $Pb(NO_3)_2$ is 56 g/100 mL H_2O at 20°C.
- It is temperature and pressure dependent
- Three categories: **soluble, slightly soluble, and insoluble**.

Solubility Rules and Double Displacement Reactions

- A double displacement reaction occurs if a precipitate forms, a gas is produced or a molecular compound like water is created.
- **Solubility rules** can used to determine if a reaction will occur in a double displacement reaction.
- If both the products are soluble (form ions in solution), then **no reaction** has occurred.

Double Displacement Reaction

$3CoCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Co_3(PO_4)_{2(s)} + 6NaCl_{(aq)}$

Will this reaction occur?

A reaction will occur only if the following will be produced

1)Gas

2)Solid precipitate

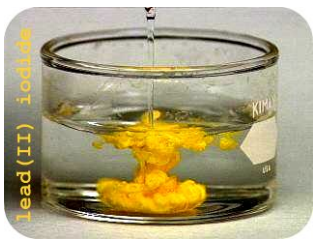
Solubility table

Ion	Solubility	Exceptions
NO_3^-	soluble	none
ClO_4^-	soluble	none
Cl^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
I^-	soluble	except Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	soluble	except Ca^{2+}, Ba^{2+}, Sr^{2+}, Hg^{2+}, Pb^{2+}, Ag^+
CO_3^{2-}	insoluble	except Group IA and NH_4^+
PO_4^{3-}	insoluble	except Group IA and NH_4^+
-OH	insoluble	except Group IA, *Ca^{2+}, Ba^{2+}, Sr^{2+}
S^{2-}	insoluble	except Group IA, IIA and NH_4^+
Na^+	soluble	none
NH_4^+	soluble	none
K^+	soluble	none

*slightly soluble

Forming an Insoluble Product

$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$



Solubility Rules (common ionic compounds in water at 25 °C)

Soluble Compounds	Exceptions
Compounds containing alkali metal ions (Li^+, Na^+, K^+, Rb^+, Cs^+) and the ammonium ion (NH_4^+)	
Nitrates (NO_3^-), bicarbonates (HCO_3^-), and chlorates (ClO_3^-)	
Halides (Cl^-, Br^-, I^-)	Halides of Ag^+, Hg_2^{2+}, and Pb^{2+}
Sulfates (SO_4^{2-})	Sulfates of Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Hg^{2+}, and Pb^{2+}
Insoluble Compounds	**Exceptions**
Carbonates (CO_3^{2-}), phosphates (PO_4^{3-}), chromates (CrO_4^{2-}), sulfides (S^{2-})	Compounds containing alkali metal ions and the ammonium ion
Hydroxides (OH^-)	Compounds containing alkali metal ions and the Ba^{2+} ion

Verifying Solubility

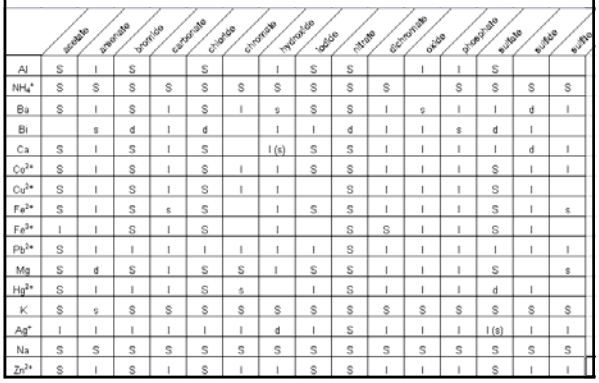
Use your solubility chart to verity if the compound is soluble in water?

a) $MgCO_3$
b) $AgNO_3$
c) $MgCl_2$
d) Na_3PO_4
e) KOH

Solubilities Not on the Table!

- Gases only slightly dissolve in water
- Strong acids and bases dissolve in water
  - Hydrochloric, Hydrobromic, Hydroiodic, Nitric, Sulfuric, Perchloric Acids
  - Group I hydroxides (should be on your chart anyway)
- Water slightly dissolves in water! (H+ and OH-)
- $SrSO_4$ is insoluble; BeI_2 and the products are soluble
- There are other tables and rules that cover more compounds than your table!

Solubility Table



Double Displacement Reactions that Produce a Gas

One product of the double displacement decomposes to give **WATER and a GAS**

This type has two steps:

1. *The double displacement*
2. *The decomposition of one of the products of double displacement to form water and a gas.*

Steps to solving double displacement reactions that produce a gas

1. Perform the double displacement:

   $Na_2CO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2CO_3(aq)$

   (Very unstable so it decomposes).

2. Perform the decomposition: convert the *unstable compound** into water and a gas. **$H_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g)$** (Recall from decomposition reactions: Acid → Non-metal oxide and water.) Trick: 1st subtract water from the formula of the acid: $H_2CO_3 - H_2O = CO_2$ (take out 2 H and one O)

3. Rewrite the original reaction and replace the acid in the original equation by water and the gas produced. **$Na_2CO_3(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$**

Double Displacement & Neutralization

Neutralization Reaction: A special type of **double displacement** reaction that produces water and a salt.

General Equation: Acid (Usually has H) + Base (usually has OH) → Water + Ionic Comp. (a salt: ionic compound produced by a neutralization reaction)

Sample Problems:

e.g. $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

- $HNO_3(aq) + NaOH(aq) \rightarrow$ _____
- $KOH(aq) + H_2SO_4(aq) \rightarrow$ _____
- $SrO(s) + HBr(aq) \rightarrow$ _____

Predicting the Products for a Chemical Reaction

$H_2O_2 \rightarrow$?

2) Is there only ONE reactant?

If yes, then this reaction is a DECOMPOSITION REACTION
So there should be two products, each being a separate element (i.e. Na, Ca, O_2, I_2, Br_2) *although that is not always the case*

$2H_2O_2 \rightarrow 2H_2O + O_2$

Predicting the Products for a Chemical Reaction

$Zn + SnCl_2 \rightarrow ?$

3) If there are 2 reactants, is one of them a pure metal on its own?

If yes, then this reaction is a SINGLE DISPLACEMENT REACTION
So the metal that is on its own must take the place of the other metal that is in the larger compound

$Zn + SnCl_2 \rightarrow ZnCl_2 + Sn$

Predicting the Products for a Chemical Reaction

$NaCl + AgNO_3 \rightarrow ?$

4) Are both of the reactants compounds?

If yes, then this reaction is a DOUBLE DISPLACEMENT REACTION
So the two metals must switch places with one another, forming two new compounds

$NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$

Predicting the Products for a Chemical Reaction

$C_8H_{18} + O_2 \rightarrow ?$

5) Is one of the reactants oxygen gas?

If yes, then this reaction is a COMBUSTION REACTION (as well as a SYNTHESIS REACTION)
So the products must be an oxide and energy. If one of the reactants is a hydrocarbon, then $CO_2 + H_2O$ are the products.

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O + energy$